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*X. Various Experiments on the Force of
Electrical Explosions. By Joseph Priestley,
LL. D. F. R. S.*

Read March 2,
1769. **M**AKING the explosion of a battery pass over the surface of a green cabbage-leaf, I observed that it left a track near $\frac{1}{4}$ th of an inch in breadth, exceedingly well defined, and distinguishable by a difference of colour from the rest of the leaf. Along this path, also, the firmness of texture in the leaf was entirely destroyed, that part becoming quite flexible, like a piece of cloth. Presently after, it turned yellow, grew withered, and became perfectly brittle.

Willing to try the effect of this explosion passing along the surface of other substances, I laid a piece of common window-glass on the path, pressed by a weight of six ounces; but it was shattered to pieces, and totally dispersed, together with the leaf on which it lay. Placing the black side of a piece of cork-wood upon it, pressed by a weight of half a pound, the leaf was not rent, but the cork was furrowed all the way, a trench being made in it about half an inch in breadth, and a quarter of an inch in depth. Laying the smooth cut surface of the piece of cork, it was furrowed all the way, as if it had been cut with a file, but not near so deep as before. Many of the small pieces, which had been rubbed off in the explosion,

plosion, remained in the furrow. Also the substance of the cork seemed to be shattered, and it was easily rubbed off, a little way into it.

I made this explosion on the surface of some red wine, in a small dish, and kept a part of the same quantity exposed in a similar manner; but I could perceive no difference between them after several days.

The track of an electrical explosion on the surface of the cabbage-leaf, being so well defined, suggested an experiment to ascertain whether there was any sensible momentum in the electric fluid, when it is rushing with violence from one side of a battery to the other. For this purpose I made the explosion pass over the leaves when they were cut in right and acute angles; so that the shortest path, from the inside to the outside of the battery, was to turn close at the angle; and observed that it was not diverted from its course, in the least degree, by the rapidity of its own motion, but that it had turned exactly at the angle, and kept as close to the opposite side, as if the motion had begun at the angle. The electric matter had, however, been evidently attracted by the veins of the cabbage-leaf, having pursued them a little way, at least having sensibly affected them, wherever it met with them in its passage.

This experiment suggested another, intended to determine whether the force of an explosion was at all diminished by being diverted from a right-lined course, and made to turn in a great number of angles. To do this, I first found, by a great number of trials, what length of a small iron wire I was able to melt with a battery of about twenty square feet, in the
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middle of a circuit of about three yards of brass wire, considerably thicker than the iron, and stretched in two right lines, suspended on silken strings. The length of the iron wire, melted in these circumstances, was about three inches. I then took the same brass wire, and fixing pins into a board of baked wood, twisted it about them, making it turn in a very great number of acute angles, and I put three inches of the same iron wire in the middle of this crooked circuit, that I had done in the straight one; so that the electric matter in the explosion was obliged to make a great number of turns at acute angles, before it could come to the iron wire; but I always found that the same length of iron wire was melted in these circumstances as in the other, and not the least difference was perceived in the force.

But though the form of the wire through which an explosion passed, made no difference in its force, I found a very remarkable difference occasioned by the length of the circuit in wires of the same thickness; and which, I own, surprized me very much.

In order to ascertain the practicability of firing mines by electrical explosions, I took twenty two yards of small brass wire (but so thick, however, that I could not have melted the least part of it by the force of any battery I have ever constructed), and extending it along a dry boarded floor, with a small piece of iron wire, and a cartridge of gunpowder about it, in the place that was most remote from the battery, I found that, upon the discharge, the wire was not melted, nor the gunpowder exploded; also the report was very faint. In other circumstances, a charge of the same battery was able to melt more than

nine inches of this iron wire ; and this same cartridge was easily fired near the battery, connected with shorter pieces of the same brass wire ; so that the diminution of force must have been owing to the length of the circuit.

In the place of this small brass wire, I substituted an iron wire one fifth of an inch thick, when about half an inch of the small iron wire was exploded ; so that the force was not lessened so much in a circuit of the thick iron wire, as it had been in one of the small brass wires. In order to judge how much of the force might be lost by nearer circuits, consisting of less perfect conductors, I joined the middle of the circuit made by the iron wire with water, in which both the wires were immersed. The effect was, that the small iron wire was only made red-hot, but not exploded as before.

Being sensible how much depended upon avoiding lesser circuits, whereby part of the fire of an explosion might return to the battery, without reaching the extremity of the circuit, where I intended the whole of its force to be exerted, in the remaining experiments, I insulated half the circuit of iron wire. There was no occasion for insulating the whole circuit ; for if there was but one passage to, or from the middle of it, there could be but one from, or to it. In this method it was easy to ascertain what loss of force was occasioned by the length of the circuit, as every other circumstance was carefully excluded ; and it presently appeared to be very considerable ; for tho' I could melt nine inches of the small iron wire at the distance of fifteen yards from the battery ; when I tried twenty yards, I found that I was just able to make
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six inches of it red-hot. The battery in these experiments was in the house, and the wires of which the circuit consisted were conveyed by filken strings into a garden adjoining to the house.

Mentioning this loss of force occasioned by the length of the circuit in electrical explosions to Dr. Franklin, he told me that the same observations had occurred to him, and that he had also been disappointed in an attempt to fire gunpowder at a distance from his battery.

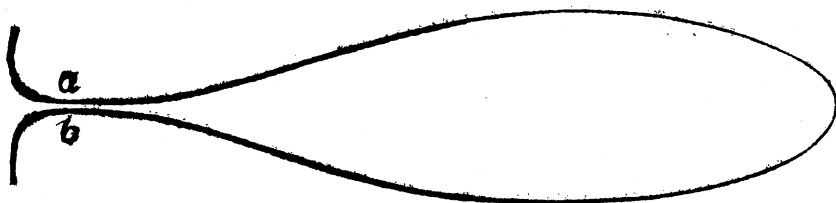
Struck with this appearance, I endeavoured to ascertain the quantity of this obstruction, by trying what other courses the electric fire would chuse preferably to a long metallic circuit. In the first place, taking about a yard of the small brass wire, mentioned above, I disposed it in the manner described below, connecting one of the ends with the outside of the battery, and the other with the inside. In the first place, I brought the parts *a* and *b* (near the two extremities) into contact, and, upon the discharge, found there had been a fusion in that place, and that a great part of the fire had taken the shorter circuit, though it had been obliged to quit the wire in one place, and enter it again in another. Afterwards I removed the parts *a* and *b* to a small distance from one another, and, upon the explosion, observed a strong spark pass between them. Removing them to greater and greater distances, I found the explosion to pass above one third of an inch in the air, rather than make the circuit of the continued wire. Using a longer and smaller iron wire, the passage through the air exceeded half an inch. I then took four or five yards of iron wire one tenth of an inch thick, when

the passage through the air was still half an inch, and taking three yards and a half of wire that was one fifth of an inch thick, the spark in the air was half an inch, and sometimes near three quarters of an inch. Making use of only half the length of this wire, the passage through the air was only half that distance, or $\frac{1}{4}$ th of an inch. When I kept the place of near contact about the middle of this wire, and made the explosion at the extremities of the whole wire, I was obliged to bring them about as near again, *i. e.* to little more than one eighth of an inch, before the passage would be through the air; so that the force of the whole explosion must have been greatly weakened by its passing through so much of the wire. Lastly, I took a pair of kitchen tongs, the legs of which were two feet, and the smallest part of them above half an inch in diameter; when the circuit was made about one sixth of an inch in the air (for at that distance from one another the ends of the tongs had been fixed) rather than through four feet of that thick iron.

Notwithstanding this evident passage of the electric matter through the air, at the same time that a metallic circuit was provided for it; it was certain that the whole of the charge did not pass in the air: for when I extended $\frac{1}{3}$ d of an inch of small iron wire between *a* and *b*, it was only made red-hot by the discharge; whereas above two inches of it would have been exploded, if there had been no other metallic circuit at all.

As the electric fire meets with so much obstruction in passing through a circuit of iron of this thickness, I make no doubt but that it is considerably obstructed
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in passing through metallic circuits of any thickness whatever ; and that it would prefer a very short passage thro' the air, if they were made even of no great length. In this method the different degrees of conducting power in different metals may be tried, using metallic circuits of the same length and thickness, and observing the difference of the passage through the air in each. N. B. A common jar answers as well, in these experiments, as a large battery. It is evident, from many experiments, that the whole fire of an explosion does not pass in the shortest and best circuit ; but that, if inferior circuits be open, part will pass in them at the same time. Of this I made the following satisfactory trial. I took an iron chain, and laid it upon a table, in contact with a charged jar ; so that the parts of it made two circuits for the discharge, which I could vary at pleasure ; and I observed that, when one of the circuits was but half an inch, and the other more than half a yard ; yet, if the charge was high, it always went in them both, there being considerable flashes between the links of the remotest part of the chain. If the charge was weak, it passed in the shortest circuit only.



It is evident, that when the wires of a battery are not in close contact, there must be some loss of force

in the discharge ; but this never appeared to me to be very considerable. In order to ascertain it by experiment, I first found, by repeated trials, what length of a piece of iron wire I was able to melt with a battery consisting of twenty jars, with the wires and connecting rods quite loose, and a chain to join the rods belonging to each row of jars, which is the manner in which I have generally constructed them. In these circumstances, I found the battery was able to melt something more than two inches and a half of the wire. I then soldered the wires of each jar to the rod which connected them, and also soldered another rod to all these, instead of the chain which I had used ; so that I avoided near a hundred sparks in the discharge, at each of which there must have been some loss of force ; but I did not find, after many trials, that the strength of the battery had been thereby sensibly diminished : for I could not melt three inches of the same piece of wire in these circumstances. It was only made red-hot, which is equivalent to the melting and exploding of little more than two inches and a half.

